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BIM and its impact upon project success outcomes from a Facilities Management perspective

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Abstract

The uptake of Building Information Modelling (BIM) has been increasing, but some of its promoted potential benefits have been slow to materialise. In particular, claims that BIM will revolutionise facilities management (FM) creating efficiencies in the whole-life of building operations have yet to be achieved on a wide scale, certainly in comparison to tangible progress made for the prior design and construction phases. To attempt to unravel the factors at play in the adoption of BIM during the operational phase, and in particular, understand if adoption by facilities managers (FMs) is lagging behind other disciplines, this study aims to understand if current BIM processes can ease the challenges in this area faced by facilities management project stakeholders. To do this, success from a facilities management viewpoint is considered and barriers to facilities management success are explored, with focused BIM use proposed as a solution to these barriers. Qualitative research was undertaken, using semi structured interviews to collect data from a non-probability sample of 7 project- and facilities- management practitioners. Key results from this study show that the main barrier to BIM adoption by facilities managers is software interoperability, with reports that facilities management systems are unable to easily import BIM data produced during the design and construction stages. Additionally, facilities managers were not treated as salient stakeholders by Project Managers, further negatively affecting facilities management project success outcomes. A 'resistance to change' was identified as another barrier, as facilities managers were sceptical of the ability of current BIM-enabled systems promoted as being FM compatible to be able to replicate their existing Computer Aided Facility Management (CAFM) legacy software and its user required capabilities. The results of this study highlight that more work is needed to ensure that BIM benefits the end user, as there was no reported use of BIM data for dedicated facilities management purposes. Further investigation into the challenges of interoperability could add significant value to this developing research area.

Keywords: BIM, CAFM, Facilities Management (FM)/Facilities Managers (FMs), Interoperability, Project Success, Stakeholders.

1. Introduction

Although Building Information Modelling (BIM) has been touted by industry bodies, government reports and academic research as a potential solution to many of the ailments afflicting the Architecture, Engineering and Construction (AEC) industry, some of the potential benefits have been slow to materialize. In particular, despite claims in research that BIM will revolutionise Facilities Management (FM) (Sabol, 2008; Arayici *et al*., 2012; Korpela *et al*., 2015) and significantly save money in building operations (Gallaher *et al*., 2004; Wijekoon *et al*., 2016), these aspirations have yet to be achieved on a wide scale, when compared to the progress made in recent years for the design and construction phases (Eadie *et al*., 2013; NBS; 2017; Ashworth & Tucker, 2017). The UK Government, in a first of two related Government Construction Strategies (2011), set a mandate for all centrally funded construction or infrastructure projects to use fully collaborative 3D BIM (or 'BIM level 2') by April 2016 (HM Government, 2011). This was followed in the GCS 2016-2020 by a commitment to "*embed and increase the use of digital technology, including Building Information Modelling (BIM) Level 2*". This approach has seemingly resulted in a strong uptake during the design stage, much slower uptake in the construction stage, and little use in the operational phase of a building (NBS, 2018). More recently, findings from the British Institute of Facilities Managements' (BIFM) survey have reinforced the claims that the FM industry are lagging behind other members of the construction industry (Ashworth & Tucker, 2017). Such surveys also reiterate the importance of ensuring that there is an earlier inclusion of FMs and clients as project stakeholders in the BIM process to ensure project success (Ashworth, Tucker & Druhman, 2019). The present paper addresses current BIM processes and the challenges faced by facilities management as project stakeholders in that process. To achieve this, success from a facilities management viewpoint is considered and barriers to facilities management success in BIM are explored.

1.1 Perspectives of Success

Success in construction project management is often judged by the 'Iron Triangle' of Time, Cost and Quality and has been used to measure the success of the PM process for decades (Atkinson, 1999). However, the 'Iron Triangle' does not consider the subsequent operational success of the project, merely management of the project delivery process (Ika, 2009). This distinction is expanded by Baccarini (1999) who splits success into two components, 'project management success' and 'end-product' success, which are independent of each other. De Wit (1988) upheld that projects can be over budget and behind time, but if the product met the quality requirements and achieved the operational requirements stipulated by the client, it could be considered a successful product, even if the management of the project had not been successful in meeting budget or time targets.

1.2 Facilities Managers as Project Stakeholders

Cooke-Davies (2002) attributes a projects long-term benefits to those involved in managing the operational phase of a building, namely the Facility Managers (FMs). FMs play a crucial role in delivering value and cost savings to the operational phase of the whole life cycle (WLC). It is estimated that 60% of operational costs of a building are attributed to the overall cost of an asset, and that 80% of these costs are influenced during the first 20% of the design process (ISO, 2017). Therefore, early inclusion of FMs expertise in construction is crucial to realising long-term cost saving and benefits of the built asset (Ackamete et al., 2010; Ashworth et al., 2016). However, there have been a number of inherent barriers associated with the integration of FMs as key stakeholders in the design and construction phase. These have included the aforementioned differences in what constitutes success, as well as poor engagement with FMs. In addition to these, there are other well documented issues such as: industry fragmentation and pervading silo mentalities (Miettinen & Paavola, 2014); inefficient collaboration; lack of communication between stakeholders (Azhar, 2011); adversarial contractual relationships; inefficient use of technology, and; poor understanding of operational requirements from other project members.

1.3 Challenges of the construction process for FMs

These barriers underpin one of the biggest challenges experienced at the operational and decommissioning stages of an asset, the flow of information. The construction process: "is highly reliant on the management, flow and usage of information… Much communication between the disciplines is normally necessary in such a process" (Tizani, 2007, p. 15). Several researchers discuss the problems in the current practice around loss of knowledge and information as a project progresses, from concept, through design, to construction, operation and finally decommissioning (Demian & Walters, 2013; Parsanezhad & Dimyadi, 2013; Yalcinkaya & Singh, 2014). Furthermore, the outputs that are delivered to FMs are usually delivered in hardcopy or e-paper as Operations and Maintenance Manuals (OMM), resulting in the information being voluminous to store, laborious to catalogue, difficult to search and slow to access (Patacas et al., 2015). This results in poor facility performance, much wasted time trying to capture, transfer and catalogue data from design and construction phases (Patacas et al., 2015, Kasprzak & Dubler, 2012). Another difficulty faced by project teams are the silo mentalities frequently experienced in practice (Miettinen & Paavola, 2014), where each part of the team works in relative isolation. This leads to individual work package optimisation rather than whole project optimization. Such difficulties are further compounded by inefficient communication (Azhar, 2011).

1.4 The Progress of BIM

Although BIM is no longer cutting-edge, it is still "seen by many as being a disruptive innovation, which is bringing about the reconfiguration of practices in the AEC industry" (Poirier et al., 2015, p. 46). BIM is more than technology change; it is a collaborative approach with the potential to be a paradigm shift in the AEC industry (Gerrard et al., 2010). The BIM process helps to manage the flow and usage of information by allowing the reuse of data, reducing the need for re-inputting of data by different specialists and reducing the chance for human error (Azhar, 2011). BIM also has potential for improving handover, as data can be exported from the model in a suitable format for FM purposes (Wu & Issa, 2012). Implicit in BIM is greater sharing of information, which enables a more collaborative working environment. In practical terms, this means using a common data environment (CDE), as a reliable single source of information (Volk et al., 2014). There is also potential for cost savings via the digital information generated during the construction process for FM purposes, with an estimate that two thirds of potential savings from BIM use would be by FMs and owners (Gallaher et al., 2004). FMs have a lot to gain from using BIM, but it is not being widely achieved. The FM Awareness of BIM (2017) report found that only 39.8% had some experience of being involved in a BIM project but only 20.5% (combined) have direct experience of writing or implementing an Asset Management Strategy in line with ISO 55000 or other system." (Ashworth & Tucker, 2017). The annual NBS BIM Surveys report increasing potential for BIM use in FM, with the number of projects producing COBie data increasing year by year, from 15% in 2012, to 23% in 2013, 27% in 2016 (NBS, 2016) and 41% in 2018 (NBS, 2018). However, in an alternative 2017 report, of 254 respondents, many noted that they were neutral with regards to the use of COBie for transfer into CAFM/other systems. It was indicated that the reason for this may be that FMs see COBie as just part of the process (Ashworth & Tucker, 2017) Many researchers have discussed this apparent lack of progress with BIM for FM, noting difficulties in defining which information is valuable for FMs and the lack of early engagement with FMs (Alwan & Gledson, 2015; Wijekoon et al., 2016).

1.5 BIM in the Operational Phase

BIM for FM is relatively new compared to the other phases of construction and, as such, there appears to be a lack of client demand. In order to get the relevant information into the model, FMs need to specify in their Asset Information Requirements (AIRs) what they want, however, "very few owners have defined these informational needs or developed an integration strategy into existing maintenance management systems" (Kasprzak & Dubler, 2012). It seems that the potential benefits of BIM to the operational phase of the building are being hampered by lack of knowledge by building owners and operators. Giel & Issa (2014, p.552) state that, “many owners are unsure of what BIM deliverables to require and lack the technical knowledge and resources required to operationalize the models they receive from designers and contractors”. The same researchers (ibid) advise, “there is a need to truly understand the information needs of FM professionals before requirements documentation are refined”, which is supported by Kasprzak & Dubler (2012, p. 68) in that, “very few owners have defined these informational needs or developed an integration strategy into existing maintenance management systems.” Other researchers point out that there are difficulties defining data requirements for FM (Yalcinkaya and Singh, 2014), and additionally prioritising which information is needed at what time during the project delivery (Kassem et al., 2015).

1.6 Conceptual Model

The concepts which have emerged from a review of the literature have been synthesized to construct a framework diagrammatically presenting the key issue and its possible causes by way of a Fishbone model (as popularized by Kaoru Ishikawa) shown in Figure 1. The ‘problem’ or key issue, is success in the operational phase of the project lifecycle, and the concepts identified in the literature are all possible causes that have an impact on operational success1.

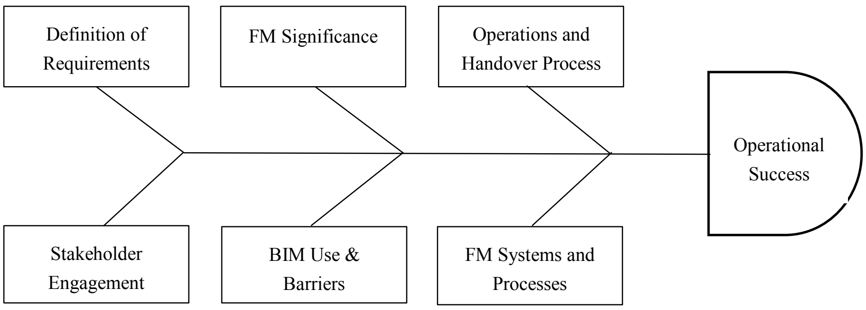

Figure 1: Theoretical model of the themes identified in the literature

2. Methodology

Qualitative research, informed by an interpretivist epistemology and an inductive approach was undertaken, using semi-structured interviews to collect data from a non-probability sample. The population of interest were project professionals from the project-, and facility-, management domains. Use of a convenience, purposive, sampling strategy afforded 7 interviews to be undertaken. These were with 4 FMs and 3 PMs, all of whom were currently engaged in construction projects and whose experience in the industry ranged from 6 – 40 years. They were drawn across five separate organisations based in the North of England, UK (see Table 1 for details of research particpants). The interview guide was distributed two weeks before each interview took place, along with a reminder letter, to enable the participants to prepare and as such generate more considered data. Use of semi-structured interviews also allowed for some question development to occur, whereby some unexpected themes that arose from the initial, early interviews could be incorporated into the research instrument. The interviews were recorded using a digital voice recorder and then transcribed. Anonymous participant numbering was also allocated to research participants. To aid thematic analysis of qualitative data, Nvivo was also used.

[1] As the research has been undertaken from a qualitative only perspective, the researchers have refrained from using terminology of independent and dependent variables here, despite how well Ishikawa models also lend themselves to quantitative analysis of cause and effect.

Table 1: Characteristics of Research Participants (RP).

RP	Role	Experience	Sector.	Organisation.
1	FM, Head of Maintenance.	40 years.	Higher Education.	1: Newcastle.
2	PM, Senior Programme Manager.	19 years.	Local Government.	2: Cumbria.
3	Project Manager.	7 years.	Higher Education.	1: Newcastle.
4	FM, Estates Planning & Development Manager.	23 years.	Higher Education	3: Sunderland.
5	FM, Senior Maintenance Supervisor.	14 years.	Higher Education.	4: Lancaster.
6	Project Manager.	6 years	Higher Education.	3: Sunderland.
7	Property and Facilities Manager.	5 years.	Heritage.	5. Durham.

3. Results and Analysis

a. Success

Prior research identifies that the 'Iron Triangle' is a commonly used method to analyse project success (Atkinson, 1999). Other researchers (Baccarini, 1999; Ika, 2009) report that PMs look at project success, while FMs are more concerned with end product success. Literature tends to identify that tight profit margins leads to adversarial approaches being taken, which along with a tendency to work in silos with poor communication can impact on success (Miettinen & Paavola, 2014). Because of these concerns, participants were asked: ***How do you judge if a project was successful?*** This question generated various responses focusing on issues such as success measurability, client and end-user satisfaction, and quality of collaborator relationships. Although not mentioned by name, many participants talked about the iron triangle, including Participant 6 (PM) who said: "*There are three key elements, time quality and cost, two are easy… quality is a lot harder.*" Operational success was mentioned by some respondents, such as Participant 1 (FM): "*Is it easy to maintain,* [and] *does it work is the fundamental one… if it doesn't work properly, it's hopeless.*" Customer satisfaction was raised as a measure of success by Participant 3 (PM): "*On time, on budget, but the main thing is if the client is satisfied.*" While Participant 7 (FM) said "*My customers are the people who work here, so as long as they get what they need… then that is the success of it.*" Several participants reported that adversarial relations were indeed common and impacted negatively on success, Participant 1 (FM) said, "*in value engineering the contractors will go to their preferred supplier and say this is what you are after, but it isn't, in reality, so we do spend a lot of time arguing with them about that.*" Silos were also mentioned as a barrier to success, even with in house PM / FM teams, Participant 6 (PM) said, "*because we maintain our own estate…we have a serious incentive to involve our FM guys. Unfortunately, that is not always very forthcoming.*"

b. Stakeholders

FMs were mentioned as important stakeholders due to the lifecycle costs of a building outweighing construction costs (Ashworth et al., 2016, Patacas et al., 2015). Participants were separately asked: (PMs) Where would you place FMs on a scale of stakeholder importance and why? / (FMs) At which points were you involved in the project delivery? PMs reported FMs as high importance, just below the end user. FMs felt that they were sufficiently engaged, but not sufficiently listened to. Participant 2 (PM) said: "I would put them up there with the likes of the project sponsor, because the FMs are going to be the ones who are operating the building and maintaining it." Lifecycle costs were important to PMs, with Participant 4 (PM) saying: "we get the money from capital for projects, but long term our revenue budgets aren't huge, so we need to make sure that we are specifying good long-term value for money." All FMs reported that they were engaged throughout the project, from early on in developing the brief, through to signing off changes due to value engineering, however their concerns were not always acted upon. Participant 1 (FM) said “once it gets through outline design and it goes to the contractors for detailed design, we are involved then and that is when the arguments start, because they want to give you something you don’t want, cos its cheap as chips for them.”

c. BIM for FM, use and barriers

Surveys of AEC professionals (Eadie et al., 2013, NBS, 2016-2018) report that BIM for FM is lagging behind BIM adoption for other purposes. Wu and Issa (2012) suggest that BIM has significant potential for FM, but it is not being realised. Participants were asked a series of questions on BIM: Do you currently use BIM, if so what for? What benefits can you see in using BIM for FM? What is stopping you from using BIM for FM? Interestingly, no participants reported currently using BIM for FM, with no one using a 3D model or asset information from a model for FM purposes, in contrast with widespread use of BIM in design, stakeholder engagement and construction. A key difficulty mentioned by several participants was that current FM software couldn’t readily import models or COBie data, despite software manufacturer claims. Participant 2 (PM) reported, “BIM is being used for design, coordination, clash detection, we are using a common data environment for the sharing documents, but not yet for FM.” Several respondents were unconvinced about the ability of BIM to meet their needs, or offer a significant improvement over their current systems. Participant 1 (FM) noted that, “I’m sceptical, because I haven’t found a software system yet that does anything near what people tell you it can do.” This was echoed by Participant 3 (PM) who said: “We have just purchased an add-on for our CAFM system to import BIM data, but it is not really able to import models and COBie data right now without a lot of fiddling and re-mapping of fields.” Lack of awareness of BIM was mentioned by several respondents, Participant 6 (PM) said “there was a significant amount of education we had to do with the FM team, even to bring them up to a basic awareness of what could be done with BIM… People are busy doing their day job, keeping up on new software advances is pretty far outside their usual role.” Several respondents pointed out that even if there was software available which could deliver, there is an element of resistance, with Participant 3 (PM) commenting “We need to make people aware within the FM crowd, because they are resistant to change, they are very traditional in the way they work.” This was echoed by Participant 7 (FM) who remarked “I think people are reluctant to change away from a system that works, even if it is not very efficient.” Other barriers such as the cost of implementing a new process and a lack of skilled staff were also reported by Participant 4 (FM), “the other thing is resource, you need someone to coordinate the process, we are struggling to deliver the projects as they are at the moment...the start-up costs are prohibitive.” This was supported by Participant 6 (PM) who said: “The complexity of changing CAFM systems and the amount of data we have makes adopting a new system quite laborious, very expensive really. Despite the potential savings it is really the upfront costs and finding the time, getting people with the right knowledge who can actually deliver the potential for us.”

d. Defining Requirements

Kasprzak & Dubler (2012) report that few owners have defined their FM requirements. This is supported by Giel & Issa (2014) who note that many owners are unsure what they require and that FMs need to be engaged to define these requirements. All Participants were asked a series of related questions: How are FM requirements for a building defined? At what point were FMs requirements discussed / mapped out? Have you developed Asset Information Requirements? Only two respondents (Participants 2 and 6) reported having comprehensive Asset Information Requirements (AIRs). Several others reported that they were developing AIRs, however everyone who had or was developing AIRs had brought in consultants to help develop their requirements, as they did not have the expertise in-house. However, some organisations had much less in the way of formal requirements and relied on looser specifications. Participant 2 (PM) reported: “we appointed a consultant to take us through that process and they drew up the Asset Information Requirements document.” Participant 6 (PM) described the process they went through to map out FM requirements, “we sat with the FM team and went through the COBie sheet, to see what information they needed, what they didn’t need, what they wanted embedded in the model, what could be linked to the model as a PDF, so we developed a full set of Asset

Information Requirements." Participant 4 (FM) commented: "We don't have a standard briefing document at the moment, that is probably what we need, but at the moment it is just using team members knowledge of historical successes and issues." Participant 7 (FM) described their process: "As part of going out to tender we write up our expectations, our requirements for O&M information and testing schedules." Participant 3 (PM) reported use of an internal design guide, which stated what type or brand of equipment to use or not use, but not what information was required to maintain it. "The briefing document is owned and updated by the FM team, it is their design bible for projects." Participant 4 (FM) noted that some asset information was requested however, "I don't think we go into that level of detail for the different assets."

e. Loss of information at handover

Many researchers note that loss of information at handover is a big problem for FM, which BIM could help to resolve (Demian & Walters, 2013, Patacas et al., 2015, Parsanezhad & Dimyadi, 2013). Participants were thus asked: Can you give me an overview of your processes for handover / receiving maintainable asset information? Do you use, or have you considered using BIM to assist with handover? Both PMs and FMs reported struggles with traditional handover practice, no participants reported using BIM data at handover. Participant 1 (FM) said "you get a pile of O&Ms with some brochures in." Some respondents reported having adopted soft landings procedures to assist with handover, such as Participant 3 (PM) who noted, "we have been operating BSRIA soft landings over the last few years." And Participant 6 (PM) who said, "we follow the FMAP42 process, which walks through all the different parts of handover." Participant 3 (PM) was keen to explore the possibilities of BIM at handover, but noted "I have not actually worked on a project using BIM which has got to that stage yet."

f. Operational Information

Studies by Gallaher et al., (2004) and Patacas et al., (2015) report challenges with O&Ms that BIM should help to solve. Participants were asked: How do you access O&Ms currently? Do you use / have you considered using BIM to assist with building operations and asset management? Participants were united in their agreement that current practices were inefficient, with either not enough information or not specific enough information being delivered. Reliance on paper and scanned documents was still widespread. None of the respondents had any success with importing COBie data into their CAFM system. Participant 5 (FM) noted: "The main problem we have is that most of the O&Ms we get are the full product catalogue, it can be difficult to get the exact information that we need out of that." Participant 1 (FM) remarked: "I could take you to a storage unit which is full of O&Ms." No-one reported successful use of a standard classification system. Participant 6 (PM) said "Our O&Ms are scanned in, we get them as hard copy or pdfs, they are put into our central database. We don't really have a standard format or naming system, which can cause issues for the maintenance guys trying to find the right information." Participant 3 (PM) reported "In terms of O&M format we have guidance notes that go out to the design team and contractors that defines exactly what needs to be where, the previous version was a bit woolly and we didn't get what we wanted." Several respondents reported struggling to import BIM data from the design and construction phase into their CAFM systems. Participant 1 (FM) noted that "the FM software providers all said, oh yeah we can do that, in reality none of them can."

4. Discussion

The data from this study broadly followed the split identified in the literature (Baccarini, 1999), with PMs more concerned about project management success and FMs giving more weight to end-product success. However, both groups reported that the best measure of success was a satisfied client or end user. The disconnect between project management success and long-term project success (Munns and Bjeirmi 1996) was raised by several respondents. Results also highlighted a disconnect between PMs assessment of stakeholder importance and how FMs felt they were treated. PMs regarded FMs with high importance as identified in the literature (Ashworth et al., 2016). However, FMs stated that their concerns were sometimes excluded due to the type of contract used, or cost implications. FMs reported being over-ridden by other demands such as meeting the project budget. Despite most of the respondents working for large public-sector organisations, there was a clear lack of BIM for FM use. A key finding, here, not widely reported in the literature, is that most FM software is still unable to readily import COBie data and 3D models in any format. However, there are now some interoperable CAFM solutions with upstream BIM workflows, meaning those identifying this as a barrier, could be demonstrating a lack of current knowledge. Despite this, and the fairly widespread uptake of BIM for design and construction, information is still nonetheless being lost at handover, or at least not being utilized by the building operators. Reluctance to change FM software was a major barrier, as is was perceived as a paradigm shift (Gerrard et. al, 2010) and a disruptive innovation (Gledson, 2016). Further reported barriers included; the cost associated with changing CAFM systems, the lack of knowledge within the FM sector of BIM capabilities and the additional cost to the project of requesting asset data in the BIM model. It was apparent from the results that there were some early adopters of BIM processes. However, there were some who were significantly further behind, reporting no standardised requirements document or no CAFM system, just a collection of spreadsheets. Most FMs reported being engaged to define requirements, but at varying levels of detail. This matches well with thoughts that most clients struggle to generate detailed requirements. The data shows that the defining of FM requirements for BIM is no longer an insurmountable barrier, but is still a significant challenge for FMs. The data collected shows no reported use of BIM for operational FM purposes, despite several respondents having completed projects which utilised BIM for design and construction and produced 3D as-built models and COBie data. This suggests that despite widespread BIM use at other project stages, information is still being lost at handover, as described by Patacas et al., (2015). Difficulty accessing operational information due to independent FM databases (Patacas et al., 2015) and, in some cases, continuing use of paper files and a lack of a standard classification or filing system was also reported. Overall FM's in this sample, were yet to be convinced about the ability of current FM software to utilise BIM data such as COBie sheets and 3D models for operational purposes and still provide the same capabilities as they have in existing FM software.

5. Conclusions, Limitations and Further Research

The aim of this study has been to understand what challenges FMs face in achieving successful outcomes using current construction project management practices and to ascertain if FMs do see BIM as a useful tool to help overcome these challenges. In the first instance there is a disconnect between the perception of success with FMs claiming that that the long-term product success of the built asset was overshadowed by the more traditional, short term project management success criteria of time, cost and quality. Despite the early engagement of FMs in the project process and the belief that FMs were seen as important stakeholders in the process by PMs, they felt that their concerns for the long-term success of the project were over ridden by demands such as meeting the project budget. Barriers to operational success identified that current FM processes were inefficient, particularly around handover with the loss of information at stage transition. In additions to this respondents also noted that adversarial relationships, silo working, working to poorly defined requirements and resistance to change were also barriers. The literature reported that BIM would enable huge efficiency savings and could revolutionise FM processes, however, A significant finding from the results found that BIM data, both 3D models and asset information was not readily compatible even with support from BIM consultants and specialist plugins for the latest FM software, they were still unable to import 3D models or COBie data into their CAFM systems. A comprehensive search of the literature brought up only one recent study highlighting that the primary barrier to adopting BIM for FM, suggesting that more research around the problem of software interoperability is needed. Whilst the findings are interesting, it must be stressed that the results from this study cannot be generalised due to the small sample size and the convenience sampling method used. However, the study has enabled the identification of several potential areas for future research: First, a quantitative survey using a probability sampling approach would help to ascertain if the findings of this study are representative of the wider FM population. Additionally, research into what barriers FMs face when developing Asset Information Requirements, as this was major challenge for many FMs and projects. Finally, a deeper technical study to gauge difficulties of interoperability between FM software and BIM outputs would benefit, as this was the primary barrier preventing FMs from utilising BIM data for operational purposes.

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Analysis of Airport BIM Implementation through Multi-Party Perspectives in Construction Technology Ecosystem: A Construction Innovation Framework Approach

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Abstract

Airports encompass highly complex and fragmented building and business systems that inaugurate high value interactions between people, places, and things. Value creation is a recurring issue in airport projects. Accordingly, as a highly important economic engine, life cycle management of airport projects through design-build-operate stages requires innovative approaches to meet ever-evolving needs of end-users. Building Information Modeling (BIM) can be considered as a key process innovation that can tackle the aforementioned issues while enhancing connectivity between different construction technology solutions. In this study, a construction innovation framework is employed to analyze airport BIM implementation processes of different parties, including the client, general contractor, consultant, and technology vendor. This framework enables the analysis of BIM implementation process based on various components such as drivers, inputs, enablers, barriers, benefits, and impacts. Multi-party perspective approach is adopted to explore these components for a large size U.S. airport project. It is found that the primary driver for BIM implementation is fast realization of quantifiable value- such as fewer safety issues provided by less rework on site- by the Owner. Major enablers are perceived as simplifying BIM processes and BIM tools interfaces according to project individuals' competencies and realizing potential synergies between different platforms and construction management processes; whereas rapid change of BIM tools and platforms, and significant resistance of upstream project personnel are regarded as major barriers. Based on the findings, determining BIM requirements and scope while avoiding ambiguity for each party enables continuous value creation throughout BIM implementation processes in an airport project. This study helps in understanding how BIM diffuses within an airport project context by articulating the dynamic relationships between key people, technology, and processes.

Keywords: Airport building information modeling (BIM) implementation, Construction innovation, Construction technology landscape, Connectivity, Multi-party collaboration

1. Introduction

In today's developing world, aging infrastructure falls short of addressing the hyper-evolving demands of the society. Modernizing and expanding infrastructure becomes increasingly important. Annual infrastructure investment needs for transport (road, rail, ports, and airports) continues to rise through 2030 to keep up with projected GDP growth; and it is estimated that an additional annual $2.5 trillion is needed in infrastructure investment through 2030 (MGI, 2013). Airports -forming one of the most important economic engines- play a crucial role within the infrastructure and urban development industry as hosting high value interactions between people, places, and things. They encapsulate various types of infrastructure, building and business systems. However, Airports Council International (ACI) World Key Performance Indicators (KPIs) (2019) reports that two-thirds of world airports are loss-making (Airports Council International (ACI) World, 2019). To increase infrastructure productivity, the delivery of projects -starting from the selection to building, and operation- should be streamlined by proven innovative practices (MGI, 2013).

Building Information Modeling (BIM) is increasingly employed as one of the most promising digital, innovative processes for transportation infrastructure projects, providing a more efficient management of network of assets in terms of scope, cost, time, quality, and resources from construction to operation (Bradley, Li, Lark, & Dunn, 2016; Costin, Adibfar, Hu, & Chen, 2018; Fortin, Bloomfield, Mahaz, & Alfaqih, 2018). According to Smart Market Report by Dodge Data & Analytics, the adoption levels of BIM use in transportation infrastructure is increasing; and 62% of the firms doing aviation projects have a higher level of BIM implementation in the majority of their projects compared to the ones having roads, bridges, rail/mass transit or tunnel projects in their portfolios. It is also reported that BIM use has been more than doubled in the US, UK, France, and Germany since 2015; and there is as a consistent trend that the designers are early adopters, and contractors are experiencing comparatively higher rate in BIM implementation despite having owner requests for BIM for roughly 35% of their projects (Petrullo et al., 2017). Increasing adoption of BIM implementation by firms with different roles focusing on aviation projects also implies the introduction of various other technology ecosystem use cases along with BIM to the airport projects. These use cases can be incorporated with the BIM implementation processes within the relevant project phases. The essential ones in which BIM technologies and processes create synergies in airport projects can be listed as 3-D modeling, lean construction, process simulation, value engineering, document management, project scheduling, design simulation (Koseoglu & Nurtan-Gunes, 2018; McCuen & Pittenger, 2016).

Moreover, connectivity between the aforementioned construction technologies and along the project supply chain network is crucial as it requires a certain level of collaboration between project parties. Because every party brings its own practices, sustaining a certain level of information flow throughout the supply chain network of the project is critical. In essence, it is important for every project participant to understand that the collaborative process within the BIM-enabled project leads to higher efficiency (Lu, Zhang, & Rowlinson, 2013). This notion becomes more complicated for airport projects as they typically have large scopes, long time periods between planning to completion; and they involve a wide variety of stakeholders (Sentence, 2013). Efficient deployment of airport BIM implementation can target challenges associated with seamless data handover between project parties and phases that occur due to siloed nature of airport projects. However, it is essential to understand the interactions both within a range of stakeholders, and between stakeholders and technology uses (Harty, 2005). Accordingly, the major objective of this study is to provide a solid understanding in how airport BIM processes can facilitate the delivery of a project by delineating the multi-party perspectives within a construction technology ecosystem.

1.1. BIM as an Innovation Process in Construction

BIM was an accepted acronym for a range of descriptions such as Virtual Design & Construction (VDC), integrated Project Models, or Building Product Models, but its single use and definition were standardized for Architecture, Engineering, and Construction (AEC) industry to holistically address planning, design, delivery, and operational processes within the building lifecycle (Dominik Holzer, 2016). Since then, BIM has been widely recognized as one of the disruptive digital innovations in the AEC sector. To explore BIM adoption's evolvement and diffusion as a construction innovation at the firm level and project level, several models, frameworks, and approaches have been suggested in the literature. It is discussed that considering the inter-organizational contexts of construction industry, BIM is an innovation that extends beyond a confined circle of application and has an inter-organizational level of effect in a project (Harty, 2005; Riitta & Hirvensalo, 2008; Shibeika & Harty, 2015). However, most of the literature has investigated construction innovation processes at the firm level, and the project level studies generally focus solely on building project case studies to analyze BIM implementation processes, lacking clear differentiation of multi-party perspectives.

BIM use facilitates the delivery of a project by enhancing the connectivity between parties and construction technology ecosystem use cases. In this study, interacting components of an innovation framework developed by Ozorhon (2013) are utilized to systematically analyze BIM implementation technology and processes from an innovation diffusion process approach in a complex large-scale project setting. The adopted framework is demonstrated in Figure 1.

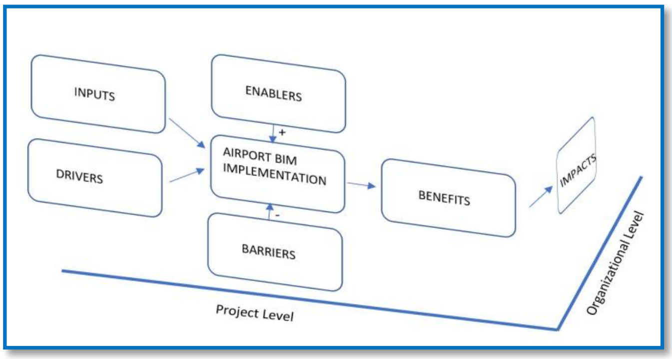

Figure 1: Framework for the Innovation Process of Airport BIM Implementation (adopted from (Ozorhon, 2013)*)*

In this framework, drivers represent main motivations for BIM implementation, and inputs represent resources utilized during the implementation process. The rate of innovation is influenced by barriers and enablers. Barriers are the primary factors that hinder BIM implementation. Enablers act as the factors that are used to overcome the barriers. The outcomes of the BIM implementation are represented by benefits which are realized at the project level. Wider outcomes are defined by impacts that are observed at the organizational or firm level in the long run. According to this framework, it is assumed that project-level benefits trigger the impacts realized at the organizational level. These components are examined in a complex large-scale airport case study to depict a clear picture of how Airport BIM implementation diffuses within a project environment from multi-party perspectives.

2. Material and Methods

This research uses a qualitative methodology, in which an explanatory case-study approach is followed via semi-structured interviews for data collection. Explanatory case studies focus on specific cases in which the theory, and its potential can be examined with the logic of replication to produce generalizations (Scapens, 1990). Also, to make conceptual generalizations from the local context of the case study to other settings, systematic collection of data from interviews, observation and documentation reviews are carried out (Seale, 1999). In this study, the fifth busiest U.S. large hub (a commercial airport classification having a minimum number of annual passenger boardings of 1 million (FAA, 2018)), Denver International Airport (DEN), is used as a case study. DEN is the largest airport in the US with 6 runways, spanning 136 km^2, and handling 61.4 million passengers annually (Dugdale, 2018). Also, DEN has been selected as the best among the 20 largest U.S. airports according to the first WSJ Airport Rankings (McCartney, 2018). The case study investigates BIM-enabled project delivery and life cycle management of DEN via focusing on DEN's completed expansion project of Hotel and Transit Center Program, containing a commuter rail transit center and a 519-room hotel, and current digital facilities and asset management practices. This case is chosen strategically to address the problem statement and to provide an in-depth analysis by answering questions of "how" and "why" (Yin, 1994) from multi-party perspectives. With an understanding of the existence of different stakeholders and different perspectives, semi-structured interviews are carried out with four different parties representing the Owner, General Contractor, Supplier (technology/software vendor), and Consultant as the owner's representative. The roles of the interviewees are provided in detail in Table 1. Each participant oversees the airport BIM implementation process within their respective organizations. As such, yielded data encompass insights on upstream to downstream activities within organizations. Semi-structured interview questions are provided in Table 2.

Furthermore, thematic analysis is used to identify patterns and themes in the qualitative data collected. Thematic analysis begins at the stage of data collection, data entry and continues throughout data coding and interpretation (Evans & Lewis, 2017). In this study, themes are determined as the components of an innovation framework, which are drivers, inputs, enablers, barriers, benefits, and impacts. The qualitative data collected via each interview question is coded with the associated themes (See Table 2). A qualitative data analysis computer software package, NVivo, is used to code the collected data to provide an in-depth case analysis by developing links between the themes and the original data coming from interviewees' answers. Themes are represented as nodes in the NVivo interface and interviewee's responses are imported as cases to the NVivo project. The coding patterns are analyzed for each case by calculating the coding percentages for each theme.

Table 1: Interviewees' Roles and Organizations

Interviewee	Role	Organization
Digital Facilities and Infrastructure (DFI) Program Manager	- Building up the DFI Program including BIM, VDC and integrations with GIS and Asset Management - Implementing the rollout of a bidirectional connection between airport BIM models and the airport asset management program - Developing workflows that improved the warranty management program by integrating it with other newly deployed platforms to create additional synergies	Owner
Senior Integrated Construction Manager	- Manage projects/teams from pre-construction through occupancy by utilizing VDC - Implementing training programs on VDC uses - Leading the integrated delivery process in pre-construction - Assisting in creation of company-wide VDC standards, and streamlining the BIM execution plan - Benchmarking emerging technologies including laser scanning	General Contractor
Principal Sales Consultant	- Offering insights and hands-on experience of innovative construction technologies - Providing pre-sales activity up to the executive level, consulting and professional services with Software as a Service (SaaS) platform, and connected BIM	Supplier (Technology Vendor)
Global Aviation Business Line Senior BIM Program Manager	- Working with owners, designers, and contractors in developing BIM processes for airport owners under all types of project delivery methods - Guiding clients in setting expectations and integrating BIM processes for comprehensive program development for integrated maintenance and management activities	Consultant

Table 2: Interview Questions with Coded Themes

Interview Questions	Theme
How do you customize an Airport BIM implementation strategy for your airport project?	Drivers, Inputs, Enablers
Could you describe how your BIM strategy addresses potential needs of the major project parties?	Drivers, Enablers
Could you describe the bottlenecks in BIM data flow between parties and/or phases of the project?	Barriers
Could you tell us your expectations for Airport BIM implementation outcomes in this project?	Benefits, Impacts
What are the current demands in BIM implementation processes considering current state of the art in the infrastructure sector?	Barriers, Drivers, Enablers
Could you tell us how you utilize BIM data?	Enablers, Benefits, Impacts

3. Results

The qualitative data collected through semi-structured interviews is systematically analyzed according to the data protocol (themes) demonstrated in Table 2 in the previous section. The coding summary, presenting the percentage of coding provided for each theme (component) by each party, is given in Figure 2.

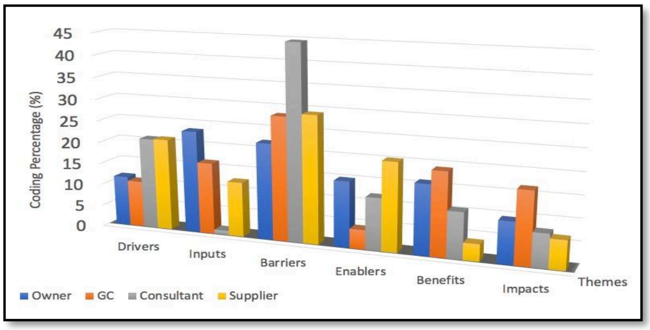

Figure 2: Coding Percentages of Themes from Multi-Party Perspectives

It is seen that 'Barriers' is the most coded component, and the rich-feedback for the barriers in airport BIM implementation shows that parties need to focus on enhancing their enablers or providing new enablers to support innovation in their projects. The Consultant has the highest coding percentage for barriers, and it is aligned with his responsibility requiring high awareness of potential challenges on the long-run to strategize optimum BIM implementation for such a large-scale project. On the other hand, the Consultant has the least input for 'Inputs' while the Owner has the highest coding percentage. This is because the Consultant sees the "big picture", but the Owner both finances and uses the BIM resources hands-on. Thus, the Consultant gives more insights on 'Drivers' as he triggers and observes BIM implementation process for different projects. However, for 'Enablers', it is the Supplier who has the highest coding percentage. Because the enablers are mainly represented by extended use of BIM technologies for better data management and utilization, the Supplier could give richer insights. Besides, more homogeneous distribution of the percentage coverage of the coding for the Owner indicates his centrality in the ecosystem as having similar levels of experience in each component. Furthermore, the Supplier has the least coverage for 'Benefits' as his project-level observation is more limited than the other parties. On the other hand, the GC realizes the benefits and impacts significantly. This highlights the higher level of BIM implementation in the design & engineering and construction phases compared to the operations and maintenance in airport projects, and also, how the GC leverages the BIM experience in the organizational level by transferring the generated knowledge to other projects.

Further analysis on each component is provided in the following sections.

3.1 Drivers

Drivers represent the main motivations for airport BIM implementation. Given the case study features, a large-scale airport project delivery requires an innovative, and more digital approach centralizing the Owner requirements (Keskin, Ozorhon, & Koseoglu, 2018). There are also common factors that drive every party to contribute to the BIM processes. Safety, eliminating cost over-runs, reducing waste, reducing time, increasing quality, effective interface management, easy management and access to the project documentation, facilitated communication and decision making, government mandates, Owner/client requirements are major drivers for parties throughout the life cycle of the project. These common drivers can also be applicable to various type of projects.

However, in the case study, from the Owner's perspective, the most prominent driver is having a record model on cloud to have certain bidirectional connectivity of the airport BIM model and the airport's asset management program for sustaining operational efficiency of the airport. This driver is also significantly emphasized by the Consultant, as it was stated that saving time via leveraging the common data environment in the operations phase, which corresponds to the 70%-90% of the total ownership cost (TOC), is more important. As the Owner side sees the value of BIM use by fast quantification achieved by the pilot projects in the construction phase, the Owner directs and obliges other parties towards BIM delivery guided by the Owner's BIM execution plan, standards, and matrices. Thus, Owner's engagement becomes one of the key drivers for other parties. Accordingly, General Contractor (GC) reported having a record model with a total of 50000 assets on cloud leading to enhanced connectivity with concurrent engineering & design and construction as a driver. Continuous realizations of value by the Owner and GC representatives increase the demand for use of BIM tools and processes. Furthermore, Owner's support also provides an optimum environment for the Supplier to set up the tools and consult the project parties for better use and integration of the tools. As such, the Supplier is driven to push the Owner to a more digitized project environment by offering integration of IoT and smart sensors to track real-time project efficiency with detection of use times of the tools, and enhanced safety on site.

It can be stated that Owner's dedicated BIM team and centralizing Owner's operational requirements are the major drivers that motivate all parties.

3.2 Inputs

Inputs are the resources utilized during the airport BIM implementation process. BIM processes can be described as the utilization of BIM tools, which are categorized as either authoring or analysis tools, and approaches to improve project phases of planning, design, construction, facility management and operations (McCuen & Pittenger, 2016). Not only BIM tools, but also other resources such as emerging technologies that can potentially be integrated with the BIM processes can be considered as inputs. BIM software, database technologies, geographic information system (GIS), complimentary technologies belong to the technology field of the BIM activity (Succar, 2009). The use of technology field is guided by the standards, execution plans, and strategies used in the project.

The Supplier, as the technology/software vendor, gave clear insights on the current state-of-practice in terms of the BIM tools used and how they sustain the information flow between parties. As the variety of BIM tools increases, platform solutions are mostly preferred by the Owners. Informative dashboards showing the number of assigned issues, clashes, documents are useful to track performance throughout the upstream to downstream activities. Not only BIM tools, but also IoT and smart sensor technologies were suggested by the Supplier as a next step in utilizing platform solutions. The Owner side, as managing and controlling the BIM delivery, reported various BIM tools including Revit, AutoCAD Civil 3D, Navisworks, BIM 360, Esri ArcGIS, Bluebeam, and IBM Maximo that correspond to the whole project life cycle. The Owner provided BIM design standards including Revit families, project coordinates, shared global coordinates, scripts to automate the BIM processes, and digital facilities and infrastructure matrix showing the required design model level of detail (LOD) at each package deliverable (LOD 100 to LOD 300). The Owner also has a strategy of mobile BIM including an inspection team of 62 inspectors and 220 mobile tablets on site for quality assurance and quality control (QA/QC) purposes. To avoid interoperability and other data exchange problems, GC also uses same authoring tools, but additionally GC tracks performance on site by using Synchro, Oracle Aconex, and Point Layout. Furthermore, the Consultant provides the BIM strategy, which is optimized according to the project resources and scale, overseeing all parties' BIM delivery responsibilities. As a common ground, it was reported that Internet of Things (IoT) and smart sensor technology can facilitate risk management by providing a more effective control on site.

Overall, each party brings in various tools and approaches to the project ecosystem to execute their own BIM scope. However, these tools and approaches should be complimentary and supportive to execute a single integrated digital platform for the project.

3.3 Barriers

Barriers are the primary factors that hinder airport BIM implementation. Lack of financial resources, lack of clear benefits, unsupportive organizational culture, lack of experienced BIM professionals, lack of awareness, lack of governmental support, and level of project complexity can be listed as major barriers of BIM implementation (Keskin et.al., 2018). These barriers can evolve overtime and can show discrepancies among different project phases and different parties. Thus, BIM adopters should determine and prioritize the most vital ones for their project considering their BIM scope at the time.

In this case study, barriers reported are mostly related to the BIM data handover and cultural barriers. Due to the collaborative nature of BIM, one party's incompetency in BIM affects other parties' practices significantly. Accordingly, lack of alignment and/or integration of complimentary practices such as GIS and BIM are some of the major challenges for the Owner. Lack of technology readiness and lack of software vendor support and/or involvement are common barriers for BIM data-handover reported by the Owner and GC. According to the Supplier, the major challenge is the siloed nature of airport projects, featuring 15 different data silos on average. Converging data spaces of each party, and highly expanded communication networks requiring approval of project documents by different parties block seamless data handover. The Supplier also stated that budget constraints and lack of technology readiness mainly hinder the BIM implementation process. These factors also hinder the involvement of the Supplier according to the Owner and GC.

Furthermore, the limited number of resources in terms of team members and BIM tools is another barrier reported by both the Consultant and the Owner. Lack of support from the governing bodies at the state and municipal levels restricts the resources for the digital facilities team to pursue competitive BIM applications such as BIM-enabled facility management (FM). A budget-based approach for asset management is preferred instead of an asset-based approach. As another common point reported by the Owner and the Consultant, the scale and complexity of the airport project, which led to a significantly large asset pool, is challenging the BIM implementation in the facility management phase. According to the Consultant, barriers for advancing BIM implementation experiences in an airport context are also more prominent because of the ever-changing retail and airline concourses. This situation makes the required updates in the BIM model significantly more challenging in the FM phase.

Even for a well strategized BIM implementation plan for design & engineering and construction phases, pushing data to FM phase is still not seamless, and requires a gap analysis considering the operational specifics of the airport.

3.4. Enablers

Enablers act as factors that are used to overcome the barriers. The key constructs of enablers of BIM implementation can be given as strategic initiatives, change management, cultural readiness, learning orientation, knowledge capability, organizational structure, and process management (Abbasnejad, Nepal, & Drogemuller, 2016). Methods and strategies developed to overcome barriers also show certain variation among different parties due to the power of authority and resources they possess.

Taking strategic initiatives to generate key control mechanisms and incentives is a key enabler for the Owner. According to the Owner, BIM is not 'visible' to all parties such as technicians on site because the main idea is to facilitate the project delivery by BIM, where applicable. If BIM use confuses parties by disrupting their work efficiencies, there is no value in enforcing BIM. Thus, BIM is not introduced to certain downstream parties who would have significantly steep BIM learning curves with no realizable contribution to their scope of work. Similarly, for parties that need to implement BIM, aligning their BIM learning curves is a major enabler for the Owner. Centralizing BIM management on behalf of the Owner is another enabler that enhances all parties' speed in BIM delivery, and asset management capabilities of the airport in the FM phase. Additionally, as the Owner manages all BIM processes, optimizing time spent on improving integration and exploring new technology is also a crucial enabler for the Owner. The Consultant's key strategy that acts as an enabler is dissolving the boundaries between project phases by implementing an integrated project delivery mindset. A similar strategy is also grasped by the Supplier as he reported that the design of BIM platforms that provide clear deadlines for every issue visible to all upstream and downstream parties is a key enabler. The Supplier also perceives real-time continuous monitoring on site as another enabler, which can mostly provide benefits to the Owner.

Moreover, both the Owner and the General Contractor perceive certain application programming interfaces (APIs) as enablers for their airport BIM implementation processes. APIs enabling real time notifications for changes in projects, files, and folders, and interacting with 3D models in a web browser with no additional software needed are considered as enablers that can defer the problems with heavy airport models and expanded, siloed communication networks within the project. They can also be beneficial throughout the whole project life cycle.

3.5 Benefits

Benefits represent BIM implementation outcomes realized at the project level. BIM benefits can be presented as the way it creates synergies between other construction technology ecosystems' uses by providing an optimum base platform to utilize metadata for various project management purposes. Multidimensional capacity of BIM in performing project management practices brings clear benefits, such as organizing project schedule and budget, better coordination with the design team, optimizing the Owner's experience and satisfaction, increased profit margin, better control of the subcontractors, project closeout with facility information rich models (Bryde, Broquetas, & Volm, 2013).

Similarly, in the case study, utilizing BIM data efficiently for key project management practices within construction technology ecosystem for different phases of the project to extract actionable insights is the common benefit for all parties. The benefit of increased connectivity between project resources is expressed as direct relation between 3D modeling, design management, document management, quality control, and enterprise geospatial information services (eGIS) by both the Owner and the GC. On top of the listed construction technology uses, GC also benefits from BIM in project scheduling, quality control, progress tracking via performance dashboards, as-built model generation, cost control and concurrent engineering & design. The Consultant, Supplier, and Owner were more focused on the enhanced operational capacity by hosting a record model, which can guide the operator in asset management practices. The Supplier paid attention to how virtually navigating the airport model can increase wayfinding efficiency for end-users. Besides, because the Consultant oversees and guides the Owner for better customization of their BIM strategy, the Consultant is also mostly concerned with translating the BIM practices into faster delivery of the project with coordinated project timelines to make such a busy airport sustain its operational capacity for its passengers.

3.6. Impacts

Impacts are wider outcomes which are observed at the organizational or firm level in the long term. Knowledge gained as project-level benefits can be reusable and transferrable to create impacts at the organizational level. Organizations can experience improvements by benefiting from such impacts.

Airports are both building and business systems, and the impacts discussed by the multi-party perspectives focus mostly on business outcomes enhanced by airport BIM implementation for the whole project life cycle. As a common sense, to realize impacts in such a complex operational ecosystem, BIM should be implemented continuously by the support of all parties. According to the Consultant, developing a competitive edge for the airport is one of the key impacts because airports are not just competing for more passengers and being airline hubs, but also for reputation, which is highly linked to the best technology implementation. In a more detailed sense, according to the GC and the Owner, transferring the digital platform to the operations phase leads to positive impacts due to improvements in airport operations metrics, such as special airport systems service time, security checkpoints wait time, and baggage delivery wait time. All of these metrics affect the business performance of an airport. The Supplier highlighted that the collaboration power can be projected to the producer – customer – consumer chain by the knowledge generated during project delivery.

4. Conclusion

The competitive landscape of the infrastructure and urban development sector requires more innovative and digitally transformative solutions that unleash significant opportunities by connecting people, technology, and space starting from the very beginning of the project. As construction technology solutions become more connected, interactions of project stakeholders also increase along the supply chain network. These interactions and their influence are more prominent in large-scale complex project settings like airports. This study contributes to the body of knowledge and practice by presenting a high level and scalable novel approach to analyze BIM implementation for airport projects from multi-party perspectives through a real-life case study. This paper also provides a systematic understanding for how each party can have an impact on the level of BIM implementation diffusion by their own perspectives in a complex airport project.

Based on the research findings, the major barrier to airport BIM implementation is the highly-siloed airport systems coupled with existence of a technology-averse team, hindering the data handover processes. The major enabler is more transparent BIM platforms used with an integrated project delivery mindset. It is also seen that the perceived impacts of successful BIM implementation for an airport project are of concern to a significant number of parties as they hold significant business value. Accordingly, it can be recommended for all project parties to have BIM implementation roadmaps defining the expected business outcomes. In addition, all factors (from multi-party perspectives) determined for each component in the innovation framework should be assessed together as they are highly interdependent. Not only data transfer, but also data utilization, by connecting the project resources and project management practices in a construction ecosystem, is crucial for leveraging airport BIM implementation for a successful project delivery.

It should be noted that the findings presented in this study are reflecting conditions observed in a specific project. Caution should be exercised while extrapolating these findings to other projects. Further studies might consider the analysis of other airport projects, as well as other types of construction projects to enable comparison of BIM implementation process in different settings. Besides, additional projects may be analyzed in different countries and comparative studies may be produced to observe the similarities and differences regarding the country-specific factors.

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